DAIRYING AND DAIRY PRODUCTS

by

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Dairying and Dairy Products

Dairying is the production and marketing of milk, usually cows' milk, and its products; it includes the care of cows, their breeding, feeding, management, and milking. The milk must be collected, processed into dairy products, and marketed. All of these operations have been studied and improved by physiological, genetic, nutritional, chemical, microbiological, technological, economic, and marketing research and development.

Historical development. Cattle, goats, and sheep have been kept by man for the production of milk throughout the time of recorded history. Milk and especially soured milks, butterlike products, and cheese were probably common foods of the peoples roaming the grasslands of Asia with their sheep and cattle thousands of years ago.

Biblical references

In the biblical narratives, Abel, son of Adam, was a "keeper of sheep," and Abraham served milk to the three divine beings who appeared to him at Hebron. Canaan was idealized as "a land flowing with milk and honey," and cheese is mentioned in the Book of Job. The Hindu Vedas, written before 1200 BC, mention the use of butter as food. In all these instances the mention of milk or its products implies much earlier use.

The ancient Europeans did not use butter as food but as a pharmaceutical, for skin injuries and sore eyes. It was widely used as a hair oil and as fuel for lamps. Whey, the watery part left after separation of the solid curd from coagulated milk, was employed widely in Europe as a medicine in the Middle Ages. Milk sugar (lactose) seems to have displaced whey as a panacea subsequent to its isolation from whey in 1628.

The Mongols in the Middle Ages prepared concentrated milks in paste, and probably in dry form, and used them as rations on the march. Commercial processes for making concentrated and dried milk did not appear until the 19th century. A patent for "the concentration of milk" was granted to Gail Borden of the United States in 1856, and the utility of canned concentrated milk was demonstrated by its use in army rations during the American Civil War. F.S. Grimwade's British patent for producing dried milk was issued in 1855, but large-scale production of dried milks did not begin until 50 years later.

The domestication and keeping of milk-producing herd animals spread from southwest Asia to other parts of the world. At first the same animals were used for work, meat, and the production of milk. The milk was consumed at the point of production as milk or as domestically made dairy products. As urban centres developed, cows and goats were kept in larger numbers to produce milk in quantity, and transportation by wagon, rail, and finally tank truck became necessary.

Early man found that goats and sheep produced enough milk for his family. As milk needs increased, the cow became established as a volume producer. The Middle Ages saw many advances in development of milk-producing breeds, and by the 18th century the practice of selective breeding was well-established. Factories to process and pasteurize the milk became accepted as a safeguard for the milk supply. The largest herds today are found within a few hundred miles of heavily populated areas and usually where abundant feed is available. Rapid transportation and advanced technology are encouraging the rise of large, specialized dairy manufacturing plants in potentially high milk producing sections distant from population centres.

In the 20th century the dairy industry of the world was well established, but it faced a challenge from the growing number of economical substitute foods, notably vegetable-base margarine, but including imitation creams, cheese dips, evaporated milks, ice creams, and even milks. Many of the simulated products employ skim milk or sodium caseinate as a protein source since there is yet no vegetable protein having the mild, pleasant flavour of milk protein.

Milk production

Milk for man is produced in largest volume in dairy countries by the cow and the water buffalo. The goat also is an important milk producer in China, India, Egypt, and in many other Asian countries. Goat's milk is also produced in Europe and North America but, compared to cow's milk, goat's milk is relatively unimportant. Buffalo's milk is produced in commercial quantities in some countries, particularly India. Where it is produced, buffalo's milk moves in the same channels as cow's milk and in some areas the community milk supply consists of a mixture of both.

DAIRY HERDS

Dairy cows are divided into five major breeds: Ayrshire, Brown Swiss, Guernsey, Holstein-Friesian, and Jersey. There are many minor breeds, among them the Red Dane, the Dutch Belted, and the Devon. There are also dual-purpose breeds used to produce milk and meat, notably the Milking Shorthorn and the Red Polled.

Breed characteristics

The Ayrshire breed originated in Scotland. Animals of this breed are red and white or brown and white in colour, and they are strong, vigorous, and good foragers. Ayrshire milk contains about 4.1 percent butterfat. Switzerland is the native home of the Brown Swiss. These cows are silver to dark brown in colour with a black nose and tongue. Brown Swiss are strong and vigorous. The average fat test of the milk is 4.1 percent. The Guernsey breed originated on Guernsey Island off the coast of France. The Guernsey is fawn-coloured with clear white markings. The milk averages about 4.8 percent fat and carries a deep yellow colour. The Holstein-Friesian originated in The Netherlands. It is black and white in colour and large in size. Holsteins give more milk than any other breed; average butterfat is 3.7 percent. The Jersey breed originated on the isle of Jersey, Great Britain. Jersey cows are fawn in colour with or without white markings. They are the smallest of the major breeds but their milk is the richest, containing on the average 5.2 percent butterfat. The protein content of milk is highest for Guernsey (3.91 percent) and Jersey (3.92 percent) and lowest for Holstein (3.23 percent).

Breeding and herd improvement. The breeds of dairy cattle have been established by years of careful selection and mating of animals to attain desired types. Increased milk and butterfat production has been the chief objective, although recently the objective has tended to shift to increased milk and protein production. Production per cow varies with many environmental factors, but the genetic background of the cow is extremely important. Production per cow for cows in the 12 highest milk-producing countries is shown in Table 1.

The principles of breeding to improve production are being applied in lesser developed countries and show promise of increasing milk production. Progress is being made in India with cows and water buffalo.

Artificial breeding has developed into a worldwide practice. Bulls with the genetic capacity to transmit high milk-producing ability to their daughters are kept in studs. Dairy-farmer cooperatives usually operate the studs, with artificial insemination generally used. Semen may be frozen for shipment to any part of the world.

Feeding dairy cattle. The dairy cow is an efficient producer of human food from roughage not digestible by humans, thanks to a unique digestive system consisting of what is really a four-compartment stomach capable of handling roughages not digested by monogastric (one stomached) animals.

Pasture is the natural feed for dairy cattle, and an abundance of good pasture provides most of the requirements of a good dairy ration. An outstanding example of grassland dairying is New Zealand, where cows are on pasture all year and milk production costs are at a minimum. The farmer does not need to prepare and store feed for a long winter period. Feeding a balanced ration, however, rather than grass alone, increases milk production. In 1970 the average annual production per cow in New Zealand was 5,511 pounds (2,500 kilograms) of milk, while in the U.S., where supplemental feeding is common, it was 9,388 pounds or 4,258 kilograms (see Table 1). Pastures of poor quality must be supplemented with other feed such as green crops, summer silage, or hay.

During seasons when pastures are inadequate, cows need hay, silage, and grain in sufficient amounts and balance to supply nutrient needs, and to guarantee a nutritional reserve to keep milk volume and composition from declining.

Disease prevention. Disease is one of the greatest problems of the dairy farm. It is a constant threat and may make removal of valuable animals from the herd necessary. One study of removal of cows from a typical dairy herd showed that an average of 22 percent of cows were removed yearly and about a third of these were lost.

Herd management

Good health herd management includes cleanliness, isolation of sick or injured animals, keeping premises free of hazards that might cause injury, and continuous protection against poisonous plants and other material. Certain diseases, such as tuberculosis, require injections. Others, such as mastitis, require constant treatment. For some diseases there is no known cure; slaughter of the animal is the only way to stop spread of the infection. Foot and mouth disease is the most notorious of these; severe measures have been taken by most governments to exclude or control it.

MILKING AND BULK HANDLING ON THE FARM

Milk is produced by the cow from her blood, and a large amount of food is necessary for maintenance of a high producing cow. The products of digestion and absorption enter the blood and are carried to the udder. There the raw materials are collected and changed into milk components. Each time the blood passes through the udder a small fraction of the components is removed to make the milk. Some 400 pounds (50 gallons, or about 200 litres) of blood must pass through the udder to make one pound (about 450 grams) of milk. A daily flow through the udder of ten tons (20,000 pounds) of blood is required for a cow producing 50 pounds (22.5 kilograms) of milk per day. The energy required to produce milk components and to circulate the blood indicates the great importance of proper and abundant feed.

Use of milking machines

Today, most milking is done with machines by a carefully trained operator, usually twice a day, in stanchion barns or milking parlors. An experienced milker handles one to three machine units. The cows are first cleaned, and the teat cups put on. Pulsating vacuum draws the milk into a receiver or through piping into the farm milk tank (see Figure 1).

Milk is an extremely perishable commodity that must be cooled to 50° F (10° C) or less within two hours and must be maintained at that temperature until it is delivered to the consumer.

Milk is transported from farm to plant in a variety of ways, depending on the part of the world. In the Gujarat region of India, the milk is carried to a receiving station in jars on the heads of women who do the milking. The receiving station transports the milk in large cans to the plant by truck.

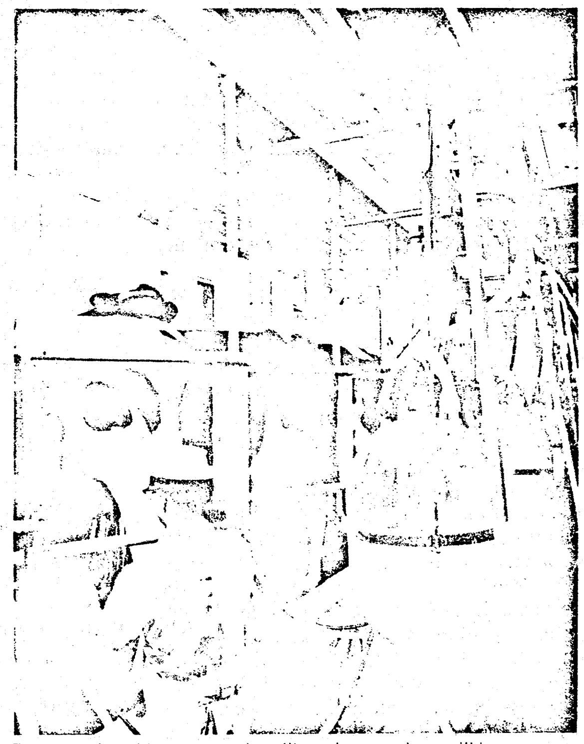

Figure 1: Attaching automatic milkers in a modern milking parlor (United States).
Grant Heilman

In the major milk-producing countries the milk is held cold in the farm tank or in cans until picked up once or twice daily by tanker or truck. Tankers pump the milk in at the farm and out into plant tanks on delivery. The tanker driver measures and samples each farmer's milk; fat and bacteria tests are run at the plant.

Pipelines have been introduced on a small scale in Europe for delivery of milk from farm to factory. Whether the method will be practical for long-range or large-scale operations remains problematical.

PRODUCTION AND CONSUMPTION STATISTICS FOR MILK

The production and utilization of milk by the largest milk-producing countries where statistics are available is shown in Table 1. The heaviest producing areas are the U.S., Europe, Australia, and New Zealand. In the U.S., almost half the milk produced is utilized in fluid form but in the dairy product exporting countries of central Europe and in Australia and New Zealand, the population requires a smaller percentage of production, leaving an exportable surplus of butter, cheese, casein, and milk sugar.

Table 1: Milk Production and Utilization in Specified Countries
(1970) Preliminary

country	production			utilization (percentage of production)				
	milk production (000,000,000 lbs)	milk cows (000,000 head)	production per cow (000 lbs)	fluid milk	butter	cheese	other uses*	feed
U.S.	117.4	12.5	9.4	46.2	20.5	16.7	15.1	1.5
France	65.5	9.6	6.9	19.7	33.1	23.4	4.6	19.1
West Germany	48.2	5.6	8.6	26.3	52.1	7.9	7.0	6.7
U.K.	27.3	4.5	6.1	68.2	12.2	11.3	4.8	3.6
Italy	20.6	3.5	5.9	36.3	14.3	32.1	2.3	15.0
Canada	18.3	2.5	7.4	32.8	42.3	13.0	8.2	3.7
The Netherlands	18.2	1.9	9.5	24.6	14.3	33.2	24.5	3.4
Australia	17.0	2.7	6.4	22.8	59.0	10.1	7.6	0.5
New Zealand	13.0	2.4	5.5	8.3	69.5	16.9	2.8	2.5
Denmark	10.2	1.2	8.9	18.5	55.7	14.8	6.7	4.3
Belgium	8.4	1.0	8.1	23.2	61.7	5.9	3.4	5.8
Ireland	8.0	1.7	4.8	18.7	47.5	7.8	10.6	15.4

*Includes milk used for ice cream, dried whole milk, canned milk, minor products, waste and balance.

Large quantities of dairy products move in international trade. Japan, the countries of Indochina, India, Central America, and other regions bordering the Equator are in general poorly suited for dairying. Where economic conditions permit, their dairy product deficit is overcome by imports. The basic requirement for a viable dairy industry is an abundance of feed and a temperate climate for cattle. Optimum conditions exist in Australia, New Zealand, the U.S., and Europe, hence the large milk production of these areas. Per capita consumption of dairy products tends to be largest in the milk-producing countries.

Prices for milk and dairy products have not increased as rapidly during the last half century as have prices of many other products. But greater economies of milk production and product processing, together with some government price-support activity, has kept profit margins attractive in most of the dairy countries.

Dairy products

Milk has been used by man to make many products both to increase variety and appeal and as a means of preservation. Almost half the milk produced in many countries is consumed as a fresh whole and skim-milk beverage type product. The remainder is manufactured into the more stable dairy products of commerce, principally butter and cheese, but including condensed and evaporated milks, dried milks, ice cream, and dairy by-products.

The following discussion of dairy products is based on cow's milk as the raw material because the processes so far developed have overwhelmingly used cow's milk. Similar processes are doubtless applicable to the buffalo's milk of India, China, Egypt, and the Philippines, the goat's milk of the Mediterranean region and elsewhere, to the milk of the reindeer, in northern Europe, and to the sheep's milk used in southern Europe. Special processing problems may be encountered with the milk of each of these species because of differences in composition and in the nature of the proteins. Simple pasteurization changes the flavour of goat's milk, and producers of this product often prefer to sell it unpasteurized. The fat of goat's milk is naturally homogenized and this is thought to improve its digestibility. Buffalo and goat milk when concentrated do not easily withstand sterilization for evaporated milk manufacture and so are rarely used for this purpose. A Cheddar-type cheese is made from buffalo milk in India, but its protein-calcium complex appears different from that of cow's milk and a way has not yet been found to cure the cheese as well as cow's milk cheese. Buffalo milk is successfully dried in India to produce powder for both infant and adult use. With research, the behaviour of the milk of various species can no doubt be adapted to the manufacture of all dairy products. The basic processes have been developed around cow's milk because of its supply and the need to preserve it for future use in distant markets.

Table 2: Average Composition of Milk of Different Species of Mammals
(percentage)

species	water	protein	fat	milk sugar	ash
Cow	87.2	3.5	3.7	4.9	0.7
Goat	87.0	3.5	4.3	4.3	0.9
Sheep	82.0	5.8	6.5	4.8	0.9
Indian buffalo	82.7	3.6	7.4	5.5	0.8
Chinese buffalo	76.8	6.0	12.6	3.7	0.9
Egyptian buffalo	82.1	4.2	8.0	4.9	0.8
Philippine carabao	78.5	5.9	10.4	4.3	0.9
Reindeer	63.3	10.3	22.5	2.5	1.4

FLUID AND CONCENTRATED MILKS

Fluid or market milk is generally considered to refer to bottled, fresh milk and its associated products, while concentrated milk refers to plain and sweetened condensed and evaporated milk.

Milk as it is secreted by the cow contains 12 to 13 percent solids. It is used in this form or it may be fermented, flavoured, or concentrated for improved utilization. It is the basic material from which all dairy products are produced. The fluid milk industry is composed of city milk plants that receive milk and process it into a variety of products, including pasteurized milk, cream, cultured buttermilk, chocolate milk, fortified skim milk, or yogurt. Specialized factories that make concentrated and dry milks, butter, cheese, and even ice cream are often located in rural heavy milk producing areas where hauling distances for the raw milk are minimal.

Composition. The same constituents are present in the milks of all mammals, but the proportions differ both among species and within a species (Table 2).

Table 3: Composition of Milk Products*

product	water (%)	fat (%)	protein (%)	lactose (%)	ash (%)	calcium (mg/100 g)	other (%)
Milk	87.0	3.9	3.5	4.9	0.7	118	
Half-and-half	80.2	11.5	3.1	4.5	0.7	108	
18% cream	74.5	18.0	2.8	4.1	0.6	102	
30% cream	63.3	30.0	2.5	3.6	0.6	85	
36% cream	58.0	36.0	2.2	3.3	0.5	75	
Plastic cream	18.2	80.0	0.7	1.0	0.1	—	
Dry cream	0.7	65.0	13.4	17.9	3.0	—	
Butter	16.0	80.6	0.6	0.4	2.4	20	
Butter oil	0.2	99.5	0.3	—	—	—	
Sweet-cream buttermilk	91.0	0.4	3.4	4.5	0.7	—	
Skim milk	90.5	0.1	3.6	5.1	0.7	121	
Cultured buttermilk	90.5	0.1	3.6	4.3	0.7	121	lactic acid 0.8
Yogurt	89.0	1.7	3.4	5.2	0.7	120	
Plain condensed skim milk	66.0	0.4	12.7	18.4	2.9	—	
Sweetened condensed skim milk	28.0	0.3	11.2	16.3	2.5	—	sucrose 42.0
Sweetened condensed milk	26.5	8.1	8.1	11.4	1.6	262	sucrose 44.3
Evaporated milk	73.8	7.9	7.0	9.7	1.6	252	
Ice cream	63.2	10.6	4.5	6.6	0.9	146	sugar 14.2
Ice milk	66.7	5.1	4.8	7.0	1.0	156	sugar 15.4
Sherbet, orange	67.0	1.2	0.9	1.4	0.1	16	sugar + trace lactic acid 29.4
Dry whole milk	2.0	27.5	26.4	38.2	5.9	909	
Dry skim milk	3.0	0.8	35.9	52.3	8.0	1308	
Dry malted milk	2.6	8.3	14.7	20.0	3.6	288	maltose and dextrin 50.5, fibre 0.3
Cheese, Cheddar	37.0	32.2	25.0	2.1	3.7	750	
Whey (Cheddar)	93.0	0.3	0.9	4.9	0.6	51	lactic acid 0.2

*These values represent average composition of consumer products, not legal minimum standards. Source: B.H. Webb and A.H. Johnson, *Fundamentals of Dairy Chemistry*, 1965, and *Composition of Foods*, USDA Handbook No. 8, 1963.

Table 4: Composition of Some Common Cheeses

	moisture (percent)	fat in solids (percent)	fat (percent)	protein (percent)	calcium (mg/100 g)	ash (percent)
Parmesan						
Typical	30.0	37.1	26.0	36.0	1,140	5.1
Federal standard*	<32.0†	>32.0‡				
Cheddar						
Typical	37.0	51.1	32.2	25.0	750	3.7
Federal standard	<39.0	>50.0				
Pasteurized process American						
Typical	40.0	50.0	30.0	23.2	697	4.9
Federal standard	<39.0	>50.0				
U.S. Swiss						
Typical	39.0	45.9	28.0	27.5	925	3.8
Federal standard	<41.0	>43.0				
Roquefort§						
Typical	40.0	50.8	30.5	21.5	315	6.0
Federal standard	<45.0	>50.0				
Limburger						
Typical	45.0	50.9	28.0	21.2	590	3.6
Federal standard	<50.0	>50.0				
Camembert						
Typical	52.2	51.7	24.7	17.5	105	3.8
Federal standard		>50.0				
Cream						
Typical	51.0	76.9	37.7	8.0	62	1.2
Federal standard	<55.0		33.0			
Cottage, creamed						
Typical	78.3	19.3	4.2	13.6	94	1.0
Federal standard	<80.0		4.0			

*Listed in approximately the order of their decreasing hardness. †< Signifies "not more than." ‡> Signifies "not less than." §Blue cheese is identical in composition.
Source: R.W. Bell and E.O. Whittier in B.H. Webb and A.H. Johnson, *Fundamentals of Dairy Chemistry*, 1965.

Many factors influence the composition of milk, including breed, the genetic constitution of the individual cow, and the interval between milkings. Since the last milk to be drawn at each milking is richer in fat than the rest, the completeness of milking influences the composition of the sample. The age of the cow, the stage of lactation, and certain disease conditions are among other factors affecting composition. In general, the kind of feed has slight effect on the composition of milk, but feed of poor quality and insufficient quantity causes both a low yield and a low percentage of nonfat solids.

The compositions of milk, creams, and various milk products are shown in Table 3. Those that contain high moisture and that are not artificially preserved by addition of sugar or by sterilization require refrigeration during storage and distribution. Most of these are products of the fluid milk industry, as distinguished from the concentrated and dry milks, butter, and ice cream. (The composition of cheeses is discussed later and shown in Table 4).

Milk is a good source of many of the vitamins, as shown in Table 5; however, only one milligram of vitamin C or ascorbic acid is present in each kilogram of milk and this is easily destroyed by heating. Vitamin D is formed in milk fat by ultraviolet irradiation, and beverage milk is now commonly fortified by additional vitamin D. Both vitamins A and D are fat soluble and are often added to skim milks to improve nutritive value.

Properties of milk. The properties of milk are important in controlling its behaviour during manufacture into various products.

Colour and flavour

The white colour of milk is caused by the fine dispersion of calcium caseinate, which is hydrated and permanently suspended in the milk. The carotenoids, largely as alpha and beta carotene (related to vitamin A) impart a natural yellow colour to the milk fat, in which they are soluble. A greenish-yellow colour in milk, noticeable particularly in whey, is caused by the presence of vitamin B_2 or riboflavin. The quantities of these pigments in milk are given in Table 5.

The flavour of milk is mild and bland unless it has been affected by the cow's consumption of strong flavour-producing feed such as wild garlic. Pasteurization changes flavour only slightly, but sterilization, as in the making of evaporated milk, imparts a definite cooked or heated flavour. This is caused by the liberation of volatile sulfides during heat treatment. Newer methods of sterilization using rapid ultra-high temperatures up to 300° F (149° C), attained in two or three seconds and held for one or two seconds, generate fewer sulfhydryls and less cooked flavour than older sterilization processes, with temperatures of 242° F (117° C) held for 15 minutes.

Other undesirable flavours can be developed in or absorbed by milk. Growth of bacteria and protein-splitting organisms can produce obnoxious flavours. Chemical changes take place when milk fat is oxidized or when a

Table 5: Vitamin Content of Some Milk Products

product	A carotene (IU/100 g)	B_1 thiamine (mg/kg)	B_2 riboflavin (mg/kg)	nicotinic acid (mg/kg)	B_6 pyridoxine (mg/kg)	pantothenic (mg/kg)	biotin (mg/kg)	B_{12} cyanocobalamin (mg/kg)
Milk	156	0.44	1.75	0.94	0.64	3.46	.031	.0043
Table cream	880	0.3	1.4	0.4	0.40	—	—	—
Butter	3,108	0.03	0.16	0.5	0.40	2.3	—	—
Skim milk	9	0.4	1.7	0.86	0.45	3.6	.016	.0038
Evaporated milk	369	0.56	3.8	2.0	0.74	7.0	.056	.0014
Ice cream	523	0.48	2.3	1.1	—	—	—	—
Cottage cheese	291	0.26	3.3	0.92	0.54	2.2	.020	.0085
Cheddar cheese	1,169	0.30	5.0	0.49	0.75	2.7	.022	.013
Whey	11	0.4	1.2	0.85	0.42	3.4	.014	.0020

Source: A.M. Hartman and L.P. Dryden in B.H. Webb and A.H. Johnson, *Fundamentals of Dairy Chemistry*, 1965.

product becomes stale. These changes are permanent and cannot be removed by further processing, but their development can be retarded by refrigerated storage, and oxidation of milk fat can be inhibited by absence of oxygen. Certain flavours imparted to milk by the cow's feed can be removed by heating the milk and passing it through a vacuum chamber.

Producing desirable flavours

Desirable flavours such as the clean lactic flavour of cultured buttermilk or of yogurt are developed by controlled fermentation of pure cultures. The characteristic flavours of various cheeses are produced by careful microbiological cultivation of the proper flora for each cheese variety. Many fruit flavours are produced in milk products by addition of fruit purees or juices.

Enzymes in milk. Milk contains many enzymes, and others are produced in milk as a result of bacterial growth. Enzymes are biologic catalysts elaborated by a living cell, in the case of milk the mammary tissue. Enzyme action in milk systems is extremely important in its effect on flavour and body of the different milk products. Lipases and other fat-splitting enzymes, oxidation catalysts, and protein-splitting proteases and starch-splitting amylases are among the more important enzymes naturally occurring in milk. These classes of enzymes and others are produced in milk by microbiological action. The proteolytic enzyme rennin, obtained from calves' stomachs, is used to coagulate milk for cheese manufacture.

Milk fat. Fat exists in milk as an emulsion in a water phase, that is, as finely dispersed globules that are stabilized by a milk protein membrane that permits clumping and gravity rise of the fat clumps. This is called creaming and it is expected in all pasteurized milk sold in bottles. In the United States, when paper cartons supplanted glass bottles, consumers stopped the practice of skimming cream from the top; processors then introduced homogenization by forcing the milk through a very small opening under pressure. This reduced the fat globules to a tenth their original size, and prevented their rapid gravity separation. Homogenization is used in many dairy processes to improve physical properties of products.

Coagulation. Coagulation of milk is an irreversible change of the milk protein from a soluble or disperse state to an agglomerated or coagulated condition. Its appearance is commonly associated with spoilage, but coagulation is a necessary step in some processing procedures. Milk may be coagulated by several agents: heat, acid, alcohol, rennet, metallic salts, certain gums, and other precipitants. Milk that naturally sours is coagulated by the lactic acid formed by the lactose-fermenting bacteria that it usually contains. When milk is pasteurized and held refrigerated for two or three weeks it will generally be spoiled if not coagulated by psychrophilic, proteolytic organisms.

Milk varies in its resistance to heat coagulation and may require many hours at 240° F (116° C) before coagulating. If the milk is concentrated, as in evaporated milk manufacture, it usually coagulates in 15 to 30 minutes at this temperature. Resistance of the concentrate against coagulation can be increased by prewarming the raw milk to a boiling temperature before concentration or by adding a minute quantity of a stabilizing salt before sterilization. Sodium phosphate is generally used for stabilization of evaporated milk.

Acidity and coagulation

Development of acid in milk by bacterial growth or addition of acid causes it to coagulate quickly during heating. Coagulation by acid is an important aid in production of special forms of milk for distribution under refrigeration in fluid markets. Cultured buttermilk is soured by controlled growth of bacteria to produce desired flavour and thick body. Yogurt is made by growing acid-forming yogurt organisms until a gellike structure is attained. Bulgaricus, koumiss, and kefir cultures make the coagulated milks named for them. Milks designed to produce a soft curd in the stomach, especially for children, can be made by treatment of the milk by a proteolytic enzyme. Some cows naturally produce soft curd milk, and the homogenization of milk will give it mild soft curd characteristics.

Processing milk. *Pasteurization.* Steps in the pasteurization of milk or cream are shown in the flow chart in Figure 2. All approved pasteurization systems are equipped with a flow diversion valve to return improperly heated milk to the raw milk side of the system in case of malfunction. The liquid-vapour separator is under partial vacuum and deodorizes the milk by removing volatile off-flavours. The bottling or packaging machine fills and seals the milk in retail containers.

Milk pasteurizers were originally of the vat type that held the milk at 145° F (63° C) for 30 minutes. Modern

Drawing by D. Meighan

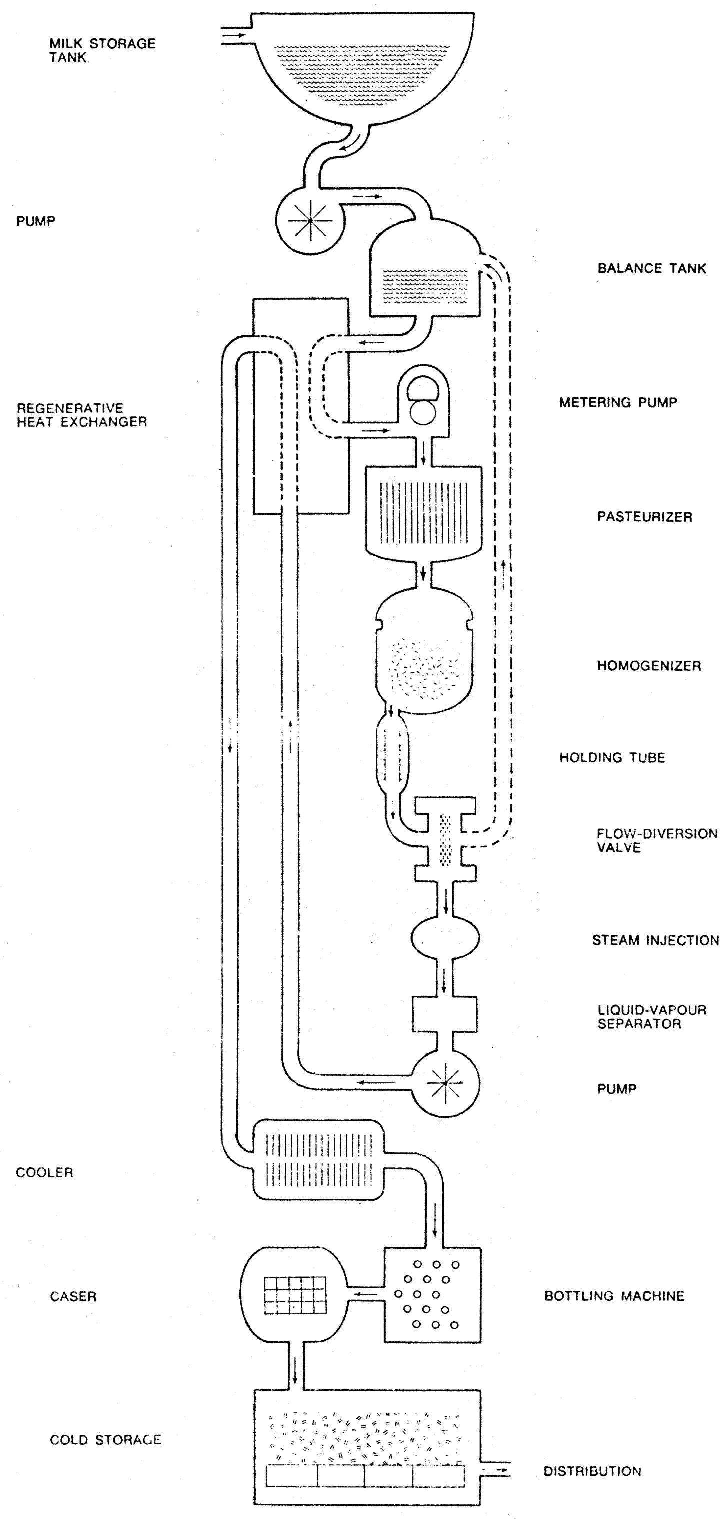

Figure 2: Milk pasteurization process.

pasteurizing equipment is designed for high temperature, short time, continuous operation between 162° F (72° C) for 16 seconds and up to 185° F (85° C) for no holding time. Pasteurizers are of the regenerative type, the hot pasteurized milk being cooled by the incoming raw product. Cream, skim milk, and other liquid products are pasteurized in the same equipment.

Separation of cream. The cream separator produces cream and skim milk, from which many dairy products are made. This machine, a high-powered centrifuge, is the successor of the gravity creaming pan. When subjected to the centrifugal force the milk-fat globules leave the plasma phase of the milk and emerge as cream from the separator bowl. Optimum separation temperature is 104° F (40° C). Efficiency is greatest when the fat globules are large, those under one micron in diameter usually remaining in the skim milk, which should contain less than 0.02 to 0.05 percent fat.

Clarification of milk. Milk clarifiers are centrifugal machines that remove extraneous matter from milk. They are built much like separators, but all the milk flows out of a single outlet, foreign material remaining in the bowl.

Quality of fresh milk products. Sanitary production and regulatory control of fresh dairy products are usually under the direction of municipal or national agencies. Inspectors regularly visit farms, plants, and distributing centres to ensure that the products are safe and nutritious.

Conditions of storage

Fresh milk, buttermilk, yogurt, cottage cheese, and allied products are very sensitive to conditions of handling and storage. Their storage life at 45° F (7° C) is usually considered to be about 15 days, but recent studies have shown that milk held at 33° F (1° C) has a storage life double that time. Thus the best practice is to hold dairy products at a temperature just above freezing.

Less rigid but safe requirements regulate the production of manufacturing grade milk, which is used in making all products except those in the fluid milk class.

Fat content may be considered an aspect of quality and, in most countries in which milk is an article of commerce, standards of composition of milk for retail sale are established by law or local regulations. The minimal standard for fat is usually some value between 3.0 and 3.5 percent, that for nonfat solids usually 8.5 percent.

Packaging fluid milk products. Milk containers in the U.S. are largely paper cartons, automatically filled and sealed by continuous machines. In countries where glass bottles are used, each bottle makes 20 to 40 trips. Returnable glass bottles are washed in automatic bottle-washing machines.

Sweetened condensed and evaporated milk. Sweetened condensed and evaporated milks are old forms of concentrated milks prepared and canned for consumer use. Their compositions are tabulated in Table 3. Sweetened condensed milk is a favourite product in many tropical countries, where it is made in modern recombining plants from dry skim milk and butter oil shipped in from dairy countries. Modified processes have been developed for the powder oil mixtures.

Sweetened condensed milk is usually made from fresh milk by adding sugar to the milk, prewarming and concentrating the mixture under high vacuum, cooling the sirupy milk so that the lactose crystallizes as very fine crystals, then canning the product. Although sweetened condensed milk thickens to a gel after long storage, it has excellent keeping qualities, being preserved by the sugar even after opening. The canned product is a consumer item used often where milk is scarce, refrigeration lacking, and temperatures such that unsweetened milk does not keep well.

Condensed milks without added sugar and without sterilization are made by pasteurizing fresh whole or skim milk and concentrating it under vacuum to about 30 to 40 percent solids. The products are cooled and held refrigerated until sold. Candy manufacturers, bakers, and ice cream processors are large users. The condensed products often are tailored to the specifications of the purchaser.

Production of evaporated milk involves several important steps. The raw milk is warmed to 203° F (95° C) for ten minutes to give its concentrate the stability needed to withstand sterilization in cans without coagulating. The milk is concentrated to a 2:1 solids content in a multiple-stage evaporator. The composition of evaporated milk is given in Table 3. The concentrated milk is homogenized, standardized, canned, and sterilized at 240° F (116° C) for 16 minutes in a high-capacity continuous sterilizer. Before sterilization the heat stability of the concentrate is adjusted with a stabilizing salt so that the body of the finished product is smooth and creamy. Improper stabilization can result in an unacceptable coagulated product.

New ultrahigh-temperature sterilization methods can be used to produce evaporated milk with only slightly more cooked flavour than pasteurized milk. In storage of such milk, flavour and body changes occur that reduce its consumer acceptance. More research is needed to improve the product.

Evaporated milk is usually fortified during manufacture with the addition of vitamin D; evaporated skim milk is fortified with vitamins A and D.

ICE CREAM AND OTHER FROZEN DAIRY PRODUCTS

Commercial production of ice cream originally grew out of the discovery that a mixture of ice and salt could produce lower temperatures than salt alone. In the late 19th century, development of mechanical refrigeration laid the basis for the modern ice cream industry.

Ice cream products are prepared for consumption in the frozen state, but many other dairy foods are frozen as a means of preservation. Frozen milk, frozen cream, frozen concentrated milk, and frozen concentrated skim milk are especially prepared for preservation by freezing and holding for future wholesale and retail use. Frozen cream and concentrated milks act as an industry balance wheel, since they are held from seasons of high production and used in seasons of scarcity.

Composition and properties. The compositions of ice cream, ice milk, and sherbet are shown in Table 3 and the quantities of the important vitamins in ice cream are given in Table 5. Fruit sherbet contains only 1 to 2 percent fat and 2 to 5 percent milk solids. All contain a maximum of 0.5 percent stabilizer and 0.2 percent emulsifier. The blend of milk fat and nonfat solids with sugar must result in a product of pleasing taste and one which is smooth and creamy. Composition is important but the most critical stage of ice cream manufacture is the mechanical blending, freezing and hardening of the frozen dessert. Even water ices on a stick, although quiescently frozen, must be frozen rapidly to prevent coarseness of body.

Use of vegetable fats and oils

Imitation ice creams known as mellorine are made in various parts of the world where economic conditions favour them. Mellorine is cheaper than ice cream because inexpensive vegetable fats and oils are substituted for milk fat. Other than this change mellorine has approximately the same composition as ice cream. There is still no satisfactory, cheap substitute for milk protein, although some vegetable proteins, particularly soy, have been prepared with improved flavour in recent years.

Manufacture of ice cream. Ice cream is a complex system in which the stable mixed emulsion of a four phase system, fat–water–ice–air, must be balanced and protected from breaking or separating. The manufacture of ice cream starts with making the mix. This is composed of a combination of suitable dairy products such as cream, milk, or skim milk either concentrated or dry. At least two mixing tanks and three aging tanks are needed to feed mix continuously to the freezer. The complete mix must be homogenized, pasteurized, and aged for at least four hours to condition it for freezing. The ice cream is extruded from the freezer into packages that are conveyed to the hardening and storage rooms.

The mix is compounded and frozen in such a way that the final product is smooth, homogeneous, and free of coarse ice crystals. Emulsifiers and stabilizers are used to finely distribute the milk fat, the ice crystals, and the air bubbles of the frozen product. Sugar in the mix is essential not only to give sweetness but also to lower the freezing point. As the water freezes the syrup becomes more concentrated, and this finally creates an unfrozen syrupy vehicle to give added smoothness and palatibility.

Incorporation of air in a mix during freezing (overrun) can double the volume. Hand freezers beat air into the mix as the water froze, but commercial freezers meter the air in under controlled conditions. The air must be incorporated and distributed as very fine bubbles.

Freezing is done with great rapidity and under severe agitation. Formation of the maximum amount of ice during freezer agitation produces smoothness. As ice forms the mix temperature is lowered until the heavy or molten product is discharged.

The common drawing temperature for batch freezers is 24° F (−5° C), when about 38 percent of the water in the mix is frozen. In the newer continuous freezers 54 percent of the water is frozen and the ice cream is drawn at 21° F (−6° C).

Scoring system for ice cream

Ice cream quality. Quality implies a cleanly produced product of acceptable flavour, body, and texture. Defects that develop in ice cream have been a challenge to manufacturer and distributor. One scoring system for ice cream reflects the problem areas. Of 100 points, 45 are given for flavour, 30 for body and texture, 15 for manufacturing facility, 5 for melting qualities, and 5 for packaging and colour. Flavour acceptability is governed by the quality of the flavouring ingredient used; *e.g.*, fruit, chocolate, or nuts. The basic flavour must come from high quality milk and cream. Body and texture are affected by physical characteristics such as freezing and storage conditions. Two principal defects are sandiness, caused by formation of noticeably large lactose crystals, and shrinkage of the product away from the sides of the package. Both of these develop rather slowly in hardening rooms or cabinets. An icy texture may result from partial melting and refreezing.

Grades and standards for ice cream permit it to be made to suit different tastes, weather conditions, and selling prices. Richness, reflected in fat content, affects both flavour and price. The usual fat content of ice cream is about 10 percent, but richer and more expensive products, such as French ice cream, may contain 12 or even 14 percent butterfat.

Ice milk contains between 2 and 7 percent fat. But with the use of stabilizers and rapid low-temperature freezing techniques ice milk can be made almost as smooth and creamy as ice cream.

Frozen dairy products. Milk and cream are sometimes frozen as a means of preserving them. The freezing point of milk is quite constant at 31.05° to 30.98° F (−0.53° to −0.58° C). A check of freezing point is a reliable method for detecting addition of water to milk. Freezing tends to destroy the fat emulsion of whole milk so that on thawing an oily fat layer forms. Homogenization before freezing almost entirely eliminates fat separation except in creams containing more than 30 percent fat. Very rapid freezing, and increase in nonfat solids, or addition of sugar also retards the amount of fat that "oils off" after thawing. Cartons of homogenized milk (not glass containers) may be quickly frozen for later use without adverse effects. Cream is frozen commercially for future use.

Fresh concentrated milk may be frozen without emulsion damage, but prolonged storage may cause the casein gradually to become insoluble.

Freezing has no observable effect on the characteristics or quality of butter and it is commonly held in cold storage at −4° F (−20° C). The freezing point of unsalted butter is 32° F (0° C) and that of salted butter −4° F (−20° C).

Because of its high sugar and lactose content sweetened condensed milk is not damaged by freezing temperatures. Its freezing point is in the vicinity of 5° F (−15° C).

The freezing points of cheeses vary from about 30° to 3° F (−1° to −16° C), depending upon moisture content. When cheese undergoes extensive freezing the body and texture become more crumbly and mealy after thawing. High-moisture cheeses such as cottage, Neufchâtel, and cream are usually seriously damaged by freezing.

BUTTER AND BUTTERFAT

From a quarter to a third of the world's milk production is used to make butter. Butter is a concentrate of butterfat or milk fat. Creams of various fat contents are intermediate products in butter manufacture. When the cream emulsion is broken, free milk fat is released and this is called butter oil or, if entirely dehydrated, anhydrous milk fat. Plastic cream is a milk fat concentrate containing up to 80 percent fat, the same fat content as butter, but with the emulsion unbroken. Plastic cream is produced by centrifugally concentrating milk fat, while butter requires not only concentration but also breaking of the fat emulsion. Various kinds of butter-like spreads containing some milk fat have been made but do not have wide recognition as standard products.

Composition. The composition of butter, butter oil, and the creams from which they are prepared is given in Table 3. Most butter contains at least 80 percent fat, not more than 16 percent water, about 2 percent added salt, and 1 percent milk curd. It is a stable mixed emulsion of fat and water but stability is lost and it oils off when the fat is melted. The fat consists largely of mixed triglycerides of fatty acids and its composition tends to vary with many factors.

Vitamins E and A and carotenoids are present in microgram quantities and these are responsible for the natural golden colour of milk fat. Vegetable colour is sometimes added in commercial production.

Characteristics of fat globules

Physical properties. The physical properties of butter and the high-fat creams and spreads stem from the unusual characteristics of milk fat as it occurs in milk. Manufacturing processes are built around the physical behaviour of the individual fat globule. Most of the globules are smaller than 4 microns (1,000 microns equal one millimetre) and they seldom exceed ten microns in diameter. The globules are covered by a protective membrane that must be disrupted to obtain butter or butter oil from cream. When the globules are destabilized by churning and, at high-fat concentrations, by homogenization, the membrane is disrupted. The rising of fat globules in milk and the formation of a cream layer represent basic properties of the fat emulsion. During rising the smaller globules clump together and the aggregates rise rapidly but without disturbance to the membrane. The centrifugal separator hastens this process by producing a plasma and a cream phase rapidly and much more efficiently than older gravity systems. The separator bowl is filled with a series of disks to channel the skim milk phase to the outside of the bowl while the lighter cream phase moves toward the centre. Separator efficiency depends upon fat content and size of the globules and the temperature of the milk, which should be 104° F (40° C).

In churning, about half the fat globule membrane material is liberated into the buttermilk. During homogenization there is a fourfold to sixfold increase in new fat surface and at high-fat levels, above about 50 percent fat, there is insufficient membrane material to cover the new surface. The system becomes destabilized and may oil off. Complete destabilization occurs in creams of 70–80 percent fat, and homogenization is used under such conditions to break the emulsion as the first step in the continuous churning process.

The hardness of the butter is affected by the physical state of the fat. When secreted by the cow in milk the fat is in a liquid state. It is partly solidified for churning by a temperature adjustment and aging at about 52° F (11° C). Temperature manipulation of the cream before churning affects the consistency of the butter. If milk fat or butter is melted and gradually cooled a large number of crystalline fractions can be obtained. Melted fat cooled to room temperature (70° F or 21° C) contains about half solid and half liquid fat. A variability in hardening temperature may be used to produce a more spreadable or an excessively hard butter at refrigeration temperature. The change in hardness is subject to further change by subsequent shifts in storage temperature.

Whipped butter has been developed to furnish a soft, easily spread butter at refrigeration temperatures. Air or nitrogen gas is whipped into softened butter by giant whippers, the product is extruded into consumer-size cartons, tubs or serving dishes and hardened in cold storage. Volume is increased about 50 percent.

Production of whipped butter

Manufacture of butter. Butter was first made by separating cream from milk by gravity, and then subjecting it to mechanical agitation. Invention of the cream separator made it possible to gather large amounts of cream in one place and this moved buttermaking from the home to the factory. Here the cream is churned and worked in wooden or metal churns (see Figure 3). Such butters are relatively uniform in appearance and physical characteristics. Continuous buttermaking, introduced after World War II, achieves increased manufacturing efficiencies and plant output. The early continuous processes tended to produce butters that lacked uniformity, but newer modifications of the process are succeeding in overcoming this difficulty.

By courtesy of F.A.O.; photograph, Prabha Art Studio, Bombay

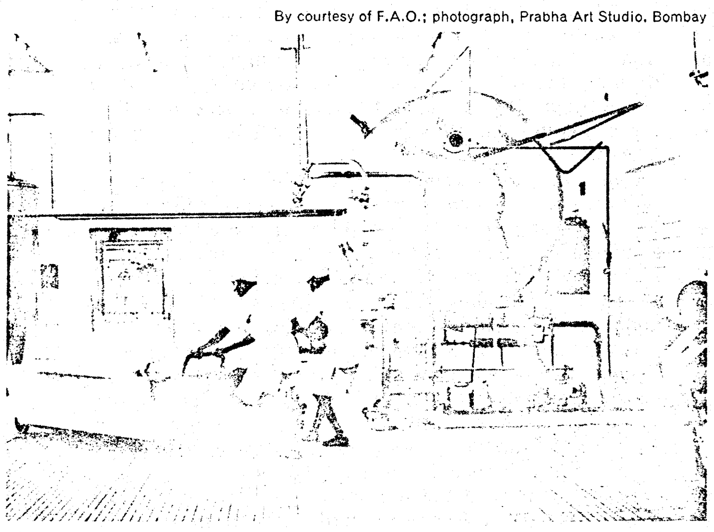

Figure 3: Bulk butter taken from a stainless steel butter churn (India).

Churning by either batch or continuous method must involve a destabilization of the fat emulsion by mechanical agitation. In the batch churning process small air bubbles are incorporated in the cream by agitation. The fat globules gather at the surface of the bubbles (at the fat–plasma interphase) until the foam collapses when butter granules are formed. The buttermilk is drained from the churn and the butter is worked to incorporate the correct amount of moisture. The butter is then chilled for 48 hours before grading.

Continuous buttermaking may be classed in two categories: methods involving the accelerated churning of cream of normal composition, and methods that utilize reseparated high-fat cream. In the first process, cream of about 36–40 percent fat moves in a thin layer through a churning cylinder. The violent agitation in the air-cream layer breaks the emulsion in a matter of minutes, compared with up to one and a half hours in the conventional churn. The air content of the butter and fat losses in the buttermilk have been troublesome but are being corrected. Factory capacity using this system has been increased from 500 to 5,000 kilograms (about 1,100 to 11,000 pounds) per hour.

The second continuous method appears to be less popular at present, but has been used extensively to prepare butter oil. The cream is pasteurized and concentrated from about 35 percent to 80 percent fat; it then goes to an emulsion breaker, usually a homogenizer. The oil is skimmed off to 98 percent fat in a second separator. If anhydrous milk fat is desired the oil goes to a vacuum dehydrator, which removes the last water to yield a 99.9 percent oil. If butter is desired the 98 percent fat product goes to a standardization tank where the required moisture, curd, and colour are added to ready the mixture for the butter worker and chiller from whence it is ready for extruding into packages.

Butter quality. Butter should be uniformly firm, waxy, and of good spreading quality, the granules close knit to cut clean when sliced. The water droplets should be well distributed throughout the mass. Some terms for body defects are "crumbly," "leaky," "sticky," and "weak." Of lesser importance in grading are colour and salt distribution.

The yellow colour of butter reflects its carotene content. The amount varies, winter butter produced on dry feed being lower in carotene than summer butter. Vitamin A is also substantially higher in summer butter. Ninety to 100 percent of the vitamin A in the milk goes into the butter. In the U.S., a harmless yellow vegetable colour, annatto, may be added to butter to improve colour uniformity throughout the year. No other additive is permitted. Vitamin D content of butter is low.

Butter from periods of high production is often held in dry storage for later movement into consumer channels at 0° F (−18° C).

Packaging. A large part of the butter produced at country plants is shipped to primary receivers who "print" and package it for distribution. Printing is the term used for cutting and wrapping the butter in consumer units. Butter is usually sold at retail wrapped in tight, moisture-proof packages.

CHEESE

An ancient legend attributes the invention of cheese to an Arabian merchant who filled his pouch made of sheep's stomach with milk and, after travelling all day, found that the milk had separated into curds and whey. The lining of the pouch contained rennet which, with the sun's warmth, caused the milk to coagulate and the whey to separate just as it does in the modern cheese vat. Some such accident may indeed have occurred; in any case, the art of cheesemaking spread from western Asia to Europe in ancient times. Special varieties developed in isolated communities in the Middle Ages, such as Gorgonzola in the Po Valley in Italy and Roquefort in the Roquefort caves of France. In the mid-19th century cheesemaking changed from a farm product to a factory industry.

Composition and properties. Cheese is a complex product and its composition is determined by a number of interrelated factors. The percentage of fat in the milk and the method of manufacture are most important. Moisture content, related to hardness, strongly influences keeping quality. Compositions of some common cheeses are shown in Table 4.

Part of the calcium and phosphorus of the milk is retained in the cheese. Essentially all of the fat and casein of milk goes to the cheese while the whey proteins (globulins and albumins), lactose, and soluble salts remain in the whey.

Varieties of cheese

There are several hundred varieties of cheese, all with somewhat different composition and properties. Most were developed gradually over a long period as a result of accidental or intentional modifications of the cheesemaking process. Today, as cheesemaking passes from an art to a science with exact chemical and microbiological control, there is better standardization and uniformity of composition.

Classification of cheese. The cheese-manufacturing process is designed to produce cheese in one of four classification groups. Group 1 is very hard grating cheese ripened by bacteria, such as Parmesan, Romano, and sapsago. Group 2 is hard cheese ripened by bacteria but without eyes, as Cheddar, or with eyes, as Swiss and Gruyère. Group 3 cheeses are semisoft and of three kinds: (1) ripened by bacteria, as brick and Muenster; (2) ripened by bacteria and surface micro-organisms, as Limburger and Port du Salut; (3) ripened by mold in the interior, as Roquefort, blue, Gorgonzola, and Stilton. Group 4 is the soft cheese of two kinds, ripened, as Bel Paese, Camembert, and Neufchâtel; and unripened, as cottage, pot, cream, mysost, primost, and fresh ricotta. Examples of the manufacturing processes for one cheese in each class are given below.

Curds and whey

Manufacture of cheese. Cheese is made by coagulating milk, cutting and heating the curd to express the whey, then pressing and ripening the cheese. The process is a microbiological one in which enzymes produced by bacteria develop the desired body and flavour. The initial coagulation may be brought about by addition of rennet, by addition of bacterial starter that develops acid by fermentation of the lactose in the milk, by direct addition of acid, or by a combination of these. To hasten curd formation the milk is held quiescent and warm for a number of hours. When congealed the curd is cut and cooked by mildly heating it to release the whey. The warm curd, containing the bacterial flora needed to produce the desired cheese variety, is pressed in suitable molds, hoops, or boxes. Some varieties (*e.g.*, cottage) are sold in the fresh state. Ripened cheeses must be held under critical temperature and moisture conditions to permit bacterial enzyme action, which creates the kind of cheese desired.

Parmesan cheese. Parmesan was first made in the vicinity of Parma, Italy. Milk or partly skimmed milk is warmed to 90°–98° F (32°–37° C) in copper kettles, a heat-resistant lactobacillus culture, plus rennet, is added to produce a firm curd in 20 to 30 minutes. The curd is placed in a hoop 10 inches (25 centimetres) deep and 18 inches (46 centimetres) in diameter and pressed for 20 hours. It is taken to a salting room and held at 62° F (17° C) for three days. The cheese is then removed from the hoop and held in brine for about 15 days, after which it is dried for 10 days. The first stage of curing consists of holding the cheese at 60° F (16° C) and 80–85 percent humidity for one year. The second stage is usually in the dealer's curing room at 54°–60° F (12°–16° C) and 90 percent humidity. It can now be sold, but it will keep almost indefinitely. Its most important use is for grating.

Cheddar cheese. Cheddar cheese was first made in the 16th century in the village of Cheddar in England. In the U.S., where almost 70 percent of the cheese made is Cheddar (often called American cheese or American Cheddar), the term "Cheddar" is used to describe both a type of cheese and a step in the manufacturing process. The most common form of the cheese is 14½ inches in diameter by 12 inches thick (37 by 30 centimetres) and weighs 75 pounds (34 kilograms).

A hard, white-to-yellow coloured cheese, Cheddar is usually made from pasteurized milk (see Figure 4). Starter, rennet, and colour are added to the milk, which sets to a firm curd in about 30 minutes. The curd is cut into small cubes and stirred continuously with warming to 100° F (38° C). About 2½ hours after the rennet is added the whey is drained and the cubes of curd are piled along the sides of the vat, where they fuse together. When the curd is firm enough to be turned without breaking, it is "cheddared" or matted; that is, cut into slabs to be turned and piled into layers. The slabs of curd are cut in a curd mill, salted, drained, and placed in cloth-lined metal hoops for pressing. After pressing the cheeses are dressed and dried for three to four days at about 55° F (13° C) before dipping them into wax. Rindless cheese can be made by wrapping it in heat-sealing plastic film. Cheddar cheeses are usually cured at about 45° F (7° C) for several months, or sometimes as long as a year.

By courtesy of the New Zealand Consulate General, New York

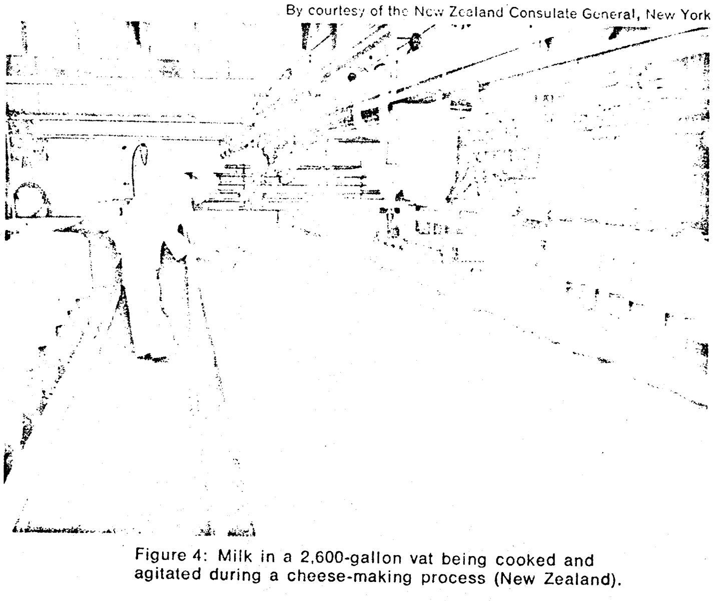

Figure 4: Milk in a 2,600-gallon vat being cooked and agitated during a cheese-making process (New Zealand).

Much effort in the U.S., Europe, and Australia has been directed toward automation of the Cheddar-making process, but it has proved difficult to mechanize the various steps without altering the sequence of chemical and microbiological changes that must occur to produce an acceptable product. Every step of the process is critical. All must be accomplished at the proper time, temperature, and acidity. The four basic steps suitable for mechanization are: (1) coagulating the milk or forming the curd; (2) draining the whey and cheddaring the curd; (3) cutting and salting; (4) pressing and handling for ripening. Two types of equipment for steps 2 and 3 have been developed in Australia.

Roquefort or blue-veined cheese. The name Roquefort is limited by French regulation to cheese made in the Roquefort area from ewe's milk; much more common is a similar blue-veined cheese made in many countries from cow's or goat's milk and often called blue cheese. Blue cheese is usually made from cow's milk by setting and cutting the curd, draining the whey, and placing the cheese in hoops. Blue mold powder grown from the mold *Penicillium roqueforti* is mixed with the curd. After 24 hours, the cheeses are removed from the hoops and dry salted over a seven to ten day period at a temperature of 48° F (9° C) and 95 percent relative humidity. A week after salting, each cheese is pierced with 40 small holes to permit air to reach the interior, air being essential for mold growth. The cheese is cured for three months and scraped and cleaned every three weeks during this time. The natural caves at Roquefort provide ideal curing conditions, 48° F (9° C) and 95 percent humidity. Suitable caves exist in other countries and artificial conditions have been successful.

Cottage cheese. Cottage is sometimes called pot or Dutch cheese, or schmierkase. It is soft, uncured, high in moisture, and perishable. Cottage cheese is made from pasteurized skim milk to which rennet and bacterial starter are added to coagulate the milk and produce flavour. The curd is cut when firm and whey is expelled from it by heat. The whey is drained from the firmed curd particles, which are then salted, creamed, and packed in 50-pound (23-kilogram) tubs or consumer-size cartons.

Process cheese. Process cheese is made by grinding fine and mixing together by heating and stirring one or more cheeses of the same kind, or two or more varieties. Soft cheeses such as cottage, cream, or skim-milk cheeses are not used. Vinegar, other organic acids, colour, spices, and flavouring may be added. Emulsifying agents help to reduce the mixture to a homogeneous mass which is then stirred and cooked at about 155° F (68° C). When ready to be packaged it is extruded into cartons lined with a transparent film that acts as a sealer to exclude air. The packaged cheese is then cooled and held under refrigeration. As made and packaged, process cheese is practically sterile and does not ripen further. Fruits, vegetables, or meats, or mixtures of these, may be added to process cheese.

Quality of cheese. Cheese is a product of fermentation except for certain fresh curd varieties made by direct addition of acid to coagulate the milk. This is a new procedure and is not yet acceptable in many areas. Fermentations constantly undergo changes that affect cheese flavour, body, texture, and colour. These are influenced by the quality of the milk, the techniques of manufacture, and the temperature and time of curing. To manufacture cheese of uniformly good quality, it is essential to use good quality milk, sanitary and adequate equipment, uniformly active starter, a standardized and proven manufacturing procedure, and controlled temperature and length of curing time.

Microbiological control to suppress unwanted bacterial and mold growth during cheese ripening is important in production of any specific variety. The making and ripening processes have been developed to encourage favourable chemical and physical changes of fermentation, proteolysis, and slight fat breakdown, and to discourage growth of organisms that produce objectionable characteristics.

Microbiological control

DRIED MILKS

Skim milk, whole milk, and certain other milk products are dried to reduce weight and shipping charges, to provide a means of handling surpluses, to prolong keeping quality, and to reduce the products to a more useful form. Besides skim milk and whole milk, dairy products or by-products that are dried include buttermilk, malted milk, sweet or sour cream, ice cream mix, whey, coffee creamers, cheese mixtures, chocolate milks, skim milk-vegetable fat mixtures, and sodium or calcium caseinates. Lactose is always prepared in dry form. Skim milk, whole milk, malted milk, and buttermilk are major dry products; the others may be considered as by-products for which there are many special uses.

Composition and properties. Composition of dry whole, dry skim, dry malted milk, and dry cream are shown in Table 3. Composition, especially fat content, may be varied over a wide range to suit special uses in food manufacture. The content of vitamin A and the water-soluble B vitamins are not seriously changed by processing into dry form. The objective of drying is to produce a dry product without seriously impairing the solubility, colour, or flavour of the original material. This can be done to a remarkable degree and a freshly dried product when remixed with water cannot usually be distinguished from its fresh pasteurized counterpart.

Manufacture of dried milks. Two general types of milk dryers are used today. The simplest and cheapest is the drum or roller dryer. A common form consists of two large metal drums that turn toward each other and are heated from the inside by steam. The concentrated liquid is applied to the hot drum in a thin sheet which is dried during one revolution of the drum then scraped off by a steel blade. The process produces a flake-like powder particle that is easily dispersed in water but that dissolves poorly. It is used in food manufacture or for animal feed.

Spray drying

The spray dryer is widely used to dry liquid materials by spraying them in finely atomized form into a stream of hot air. The large droplet surface causes rapid evaporation of moisture and provides a highly soluble powder. The drying chamber may be conical, rectangular, or silo-shaped. The dry powder passes from this chamber through a series of cyclone collectors for separation from the drying air. About three pounds of steam are required to evaporate each pound of water. The product to be dried is heated, condensed to 45 to 50 percent solids, sprayed into the dryer, and collected as powder. The process may include foam-spray drying. This is a new modification and involves injection of gas, usually air, into the high-pressure line before the spray. The gas expands the droplet and causes it to dry easily into a light low-density particle.

Spray-dried milk is difficult to mix with water, and to improve its dispersibility a process called agglomeration or instantizing has been developed. This consists of quickly moistening the fine powder particles and causing them to stick together. The instantizing process produces only limited improvement in dispersibility of fat-containing dairy products, and it is not used for dry whole milk. Most powders can be made to dissolve readily when they contain sugar, particularly if they are dry-blended with sugar.

Buttermilk is either spray- or roller-dried. Malted milk consists of approximately half milk solids and half solids from a mash prepared from barley malt and wheat flour. It is usually made by evaporating the mixture to dryness under a vacuum.

Whey is roller- or spray-dried, but, because of its high lactose content, it presents special drying problems. The milk sugar is best crystallized after concentration and before drying since its presence in the dry powder in a noncrystalline condition is conducive to moisture pickup and caking of the powder.

Quality of dried milks. Unusual sanitary precautions are taken to avoid contamination of the powder with salmonella organisms. All skim-milk powders are examined and must be free of these organisms. Whey is a perfect growth medium as it is drained warm from the cheese curd and for food use must be pasteurized and cooled at once, after which it can be held for condensing and drying.

Packaging, marketing, and distribution. Dried milks must be packaged to preserve flavour and physical characteristics. When packaged and distributed under favourable conditions dried whole milk and buttermilk will keep six months, while the skim milks and malted milks may be held up to 18 months. Stored milk fat in any form is subject to flavour changes caused by oxidation. Dried whole milk is packed in tins in an oxygen-free atmosphere and should be stored in a cool place, preferably under 45° F (7° C). Dried buttermilk contains traces of an unstable fat fraction and is best handled like whole milk. It is used in wholesale food preparation.

Keeping characteristics

The dried milks and wheys readily absorb moisture, and packaging and storage must ensure against water pickup. The products contain about 3 percent moisture as made but readily absorb water to 5 or 6 percent, which causes rapid deterioration of flavour, caking, and lowered solubility of the milk proteins. Instant dried nonfat milk is packed in tight paper boxes or envelopes; it may be quickly dispersed in water with little or no stirring or shaking, and there should be no settling of insoluble protein on refrigerated storage. Once mixed with water the milk must be held under refrigeration.

Malted milk contains a natural antioxidant, and chocolate malted milk, especially, will keep in a dry environment at room temperatures for at least 18 months.

DAIRY BY-PRODUCTS

Skim milk, buttermilk, casein, whey, and whey components including lactose or milk sugar, are by-products of the dairy industry. They have high nutritive value and are used for human and animal food and to a lesser extent for industrial purposes. Most of the price paid for milk is for the fat and thus by-product prices are relatively low, the major items contributing to their cost being transportation, manufacture, distribution, and selling. Early in the 20th century farmers were separating their milk, selling the cream, and feeding the skim milk to farm animals. Today skim milk is valued as an important human food supplement and as a source of casein and lactose, which are prepared from it. Whey is a by-product of cheese and casein manufacture and is an important source of whey protein and lactose. Buttermilk is a by-product of the churning of cream. In the past the cream often was sour, leaving a buttermilk fit only for animal food. Today, most butter is made from sweet cream and the buttermilk has become a valuable food component.

Composition. The composition of skim milk, buttermilk, and whey are shown in Table 3. Extra grade casein contains 95 percent protein, a maximum of 10 percent moisture, 1.5 percent fat, and 2.2 percent ash. Lactose or milk sugar is the carbohydrate obtained from whey, and it should be at least 99 percent pure. Casein and whey protein are sometimes prepared by a single precipitation, and the composition of the coprecipitate may be 83 percent protein, 1 percent lactose, 1.5 percent fat, 10.5 percent ash, and 4.0 percent moisture.

Physical properties. The physical properties of the by-products differ greatly, depending upon their composition. The state of the protein and lactose is of major interest to the food manufacturer and the consumer since this affects the physical properties of the food. The casein of skim milk is uniformly dispersed but it can be flocculated or coagulated by acid, enzymes, or heat. Coagulation is accompanied by an uptake of water, which causes thickening and the building of body or structure in the food. The coagulum is unstable and syneresis or wheying off will occur with time or heating, similar to the whey separation in cheesemaking. Casein is coagulated to re-

Casein of skim milk

move it from the milk. To make it redispersable for use as food it is prepared as sodium caseinate, which will reabsorb water and rebuild a structure. Whey protein differs from casein in that it is acid soluble but very sensitive to heat, coagulating at temperatures below the boiling point of water.

Lactose, which makes up half the solids of skim milk and three fourths of the solids of whey, is much less soluble than most other sugars. At room temperature lactose is saturated in water at a 17 percent concentration. On a scale of sweetness on which sugar is 100, lactose is only about 20. If lactose crystals form in a food such as ice cream or sweetened condensed milk they are kept to a very small size to avoid giving a sandy texture.

Manufacture of by-products. Manufacture of skim milk, whey, and sweet cream buttermilk for food use follows conventional lines of vacuum concentration and drying. Sometimes these products are used in condensed form and the lactose is crystallized with stirring to produce fine crystals. Drying may be either by the spray or roller methods, the spray system producing the higher quality product. Buttermilk as a by-product of buttermaking is not to be confused with cultured buttermilk, which is sold fresh, never in the dried form. Cultured buttermilk, once dried, will not reabsorb water. Dried sourcream buttermilk is suitable only for animal feed.

Processing of whey presents a special problem because small cheese factories cannot afford concentrating and drying equipment, and whey cannot economically be hauled over long distances. Reverse osmosis or membrane filtration to concentrate whey to 25 percent solids, thus reducing hauling costs, is being advanced as a solution. In any processing scheme for whey the extreme perishability of the product must be considered.

Casein is made by precipitating it from skim milk by the addition of an acid, usually hydrochloric. The precipitated casein is washed, dried, and ground. Skim milk can be naturally soured, and the lactic acid thus formed acts as the acidulant.

Lactose is produced from whey by heat coagulating and removing the whey protein, concentrating the clear whey, then crystallizing the lactose and removing it by centrifugal separation. A pure sugar is obtained by redissolving the sugar, clarifying, decolourizing, and concentrating the syrup, then centrifuging it.

Quality of by-products. The world shortage of food and a realization of the high nutritional value of milk components have led to the development of rigid quality standards for the sanitary production of milk by-products. Rigid bacteriological control is necessary since skim milk, buttermilk, and whey all contain 90 percent or more water and are excellent media for bacteria growth. By-products are usually packaged in multiwall paper bags, often with a moisture-tight lining.

DAIRY PRODUCTS IN HUMAN NUTRITION

Milk and dairy products are accepted in many countries as basic foods, some of which persons of all ages should have every day. The precise role of the milk components —protein, fat, lactose or carbohydrate, and minerals—in human nutrition is still incompletely understood. But these essential elements of a balanced diet are combined in the proportions and amounts needed for the growth of infants and children and for the dietary well-being of an adult. Indeed, the milk of each species is a complete food for its young. One pint of summer milk contributes about 90 percent of the calcium, 30 to 40 percent of the riboflavin, 25 to 30 percent of the protein, 10 to 20 percent of the calories and vitamins A and B, and up to 10 percent of the iron and vitamin D needed by an adult. Although milk supplies a higher proportion of the daily needs of a five-year-old child for calories, protein, vitamins A, B_1, and B_2, the contribution of the calcium needs is reduced to about 70 percent because of the higher calcium requirements of a child.

Food values of milk

Milk protein is of high nutritional value, since it contains all the essential amino acids; *i.e.*, those that cannot be synthesized in quantity. Eighty-two percent of milk protein is casein and 18 percent whey protein. The nutritional response to casein or to whey protein is quite uniform, and these proteins, especially casein, are used as a protein reference standard in feeding experiments. Because cow's milk contains proportionally more casein and less lactose than human milk, it is usually recommended that, for babies' formulas, water and lactose be added to cow's milk.

The nutritional value of milk fat is still unclear. It is the most complex of the natural fats, containing at least 142 fatty acids. Its composition varies widely, depending upon such factors as the cow's intake of unsaturated fatty acids and the levels of dietary fat, protein, and roughage eaten. Considerable research has been done on the possible involvement of milk fat in cardiovascular disease in man but no conclusions can yet be drawn as to what effects this or other fats may have on this ailment.

Lactose, or milk sugar, is a product of mammalian metabolism secreted in milk for nourishment of the young. Its exact nutritional function is not known, but its role in a number of metabolic processes has been studied. Lactose is hydrolyzed in the body to glucose and galactose. Glucose is absorbed directly. Galactose is considered a dietary essential because of its occurrence in cerebrosides and mucopolysaccharides. A deficiency of these is thought possibly to lead to diseases of structural and nervous tissue in later life. There is increasing evidence that a lactose intolerance produces mild or even severe digestive disturbances and diarrhea. Symptoms have been produced in individuals, most often of non-Caucasian races, by feeding 50 grams of lactose in water or even in milk or whey. It is not known whether the intolerance is genetic or whether it has been acquired by long omission of milk from the diet. Intolerance appears to be caused by the absence of the enzyme lactase in the intestine.

There are interrelationships between milk minerals and other food nutrients that are still not clear. Many minerals are involved in maintaining the balance of mineral ions in body fluids, in regulating the metabolism of enzymes, in keeping an acid-base balance, and in facilitating membrane transfer of essential compounds. The mineral content of milk includes calcium and phosphorus adequate for normal skeletal development. The dietary essential minerals that occur in major amounts in milk are, in grams per quart: potassium 1.31, calcium 1.18, chlorine 0.97, phosphorus 0.91, sulfur 0.28, and magnesium 0.11.

The nutritionally essential elements that occur in milk in minor amounts, in milligrams per quart, are: zinc 3.6, iron 0.95, copper 0.28, iodine 0.20, fluorine 0.15, manganese 0.019, molybdenum 0.069, cobalt 0.0006. Other minerals in milk occur only in trace amounts.

Milk contains all of the vitamins known to be required by man. The quantities of water soluble vitamins in a quart of milk are shown in Table 6. Milk contains the fat-soluble vitamin A and carotene, its precursor, but the amount varies considerably with the food of the lactating animal. Since green food is the main source of this vita-

Table 6: Water-Soluble Vitamins in Milk

	mg/qt
Choline	123
Inositol	123
Ascorbic acid	15
Pantothenic acid	3.31
Riboflavin	1.49
Niacin	0.80
Vitamin B_6	0.45
Thiamine	0.40
p-Aminobenzoic acid	0.1
	μg/qt
Biotin	33.10
Vitamin B_{12}	5.28
Folic acid	2.17

Source: M.F. Brink in B.H. Webb and E.O. Whittier, *Byproducts from Milk*, 1970.

min in the diet of cows, summer milk usually has more than winter milk. In recent years some commercial producers have fortified milk with the addition of vitamins and sometimes of iron.

DAIRY INDUSTRY ORGANIZATIONS

Types of organizations

The dairy industry is organized in rural and urban areas on a local, national, and international basis. The organizations represent farmers, processors, distributors, suppliers, engineers, educators, industrial and research scientists.

The International Dairy Federation, with headquarters in Brussels, consists of member countries throughout the world. It sponsors an International Dairy Congress at four-year intervals, the 18th such congress having been held in Sydney, Australia, in 1970. The 19th congress is scheduled for New Delhi, India, in 1974. The congresses include reviews of research and industrial progress and exhibits of new dairy industry equipment.

The United Nations Food and Agriculture Organization (FAO), Rome, and United Nations Children's Fund (UNICEF), New York, have made significant contributions to international dairying. Their attention has been directed especially toward increasing the production and utilization of milk in the less developed countries. FAO has sponsored studies in production, processing, and distribution of milk and its products. UNICEF has been the motivating force for establishing a dairy industry in many underdeveloped countries. One of these is India, where large, modern processing plants have been set up to process locally produced milk or to reconstitute milk from donated or purchased milk fat and powder. Domestic milk production is increasing in India, and part of the pasteurized milk is provided free to children in the larger cities through UNICEF auspices.

An outstanding example of a UNICEF-aided activity in India is the Bombay Milk Scheme, which furnishes pasteurized milk for the people of Bombay. Two hundred miles (about 300 kilometres) north of Bombay at Anand is Amul Dairy, a milk-processing cooperative that has developed a daily milk intake of 500,000 litres milked from water buffalo. Under agreement with UNICEF, 200,000 litres of this milk is shipped to Worly Dairy in Bombay for distribution in the city milk stations, the remainder being processed into powder, concentrated milks, and cheese. Amul Dairy operates a feed mill and offers complete veterinary services for its members. A successful example of a complete food-producing unit, Amul Dairy is being copied in other parts of India with assistance from UNICEF, the Indian government, and some of the large milk-producing countries of the world. These organizations have sponsored the Indian Dairy Development Board (Anand) and the Indian Dairy Corporation (Baroda), which derive support from the sale of milk from donated butter oil and milk powder.

The kind of national and local dairy organizations within a country vary widely. They are sponsored by governments, farmer cooperative groups, industrial processors, suppliers, or marketers, and institutional research and development organizations.

The first cooperative artificial breeding association was organized in Denmark in 1936. There are now many such associations, which use a few highly selected bulls to breed large numbers of cows.

Regulatory agencies operate in all advanced countries, supported by either local or national governments. The dairy industry has always been strictly regulated because it is concerned with a basic but highly perishable food in which contaminating organisms can grow quickly to dangerous numbers. Most municipalities require inspection of the cattle, the farm, trucks, and factories.

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(B.H.We.)

Dakar

Dakar, capital of Senegal, is situated close to Africa's westernmost point. Its strategic and impressive site, and the importance of its port and airport, make it one of Africa's major cities. From 1904 to 1959 it was the capital of French West Africa, and from 1959 to 1961 of the Mali Federation. The name comes from *dakhar*, a Wolof name for the tamarind tree, as well as the name of a coastal village inhabited by members of the local Lebu tribe, which lies south of what is now the first pier. The population of the metropolitan area is about 660,000.

History. European settlement in the Dakar area began when the Dutch bought the islet of Gorée, near Dakar Point, in 1617; it was captured by the French in 1677. In Anglo-French wars, Gorée was taken by the British five times; in peacetime it was a calling point for French East Indian ships, a centre of the slave trade, and, finally, a base for the suppression of the slave trade.

French occupation

The mainland was occupied by France in 1857. A pier was built on Dakar Point, and in 1866 French steamships serving South America began to call there to take on coal. The next impetus to development came with the opening in 1885 of West Africa's first railway, from Saint-Louis to Dakar. The object was to replace Saint-Louis, the port for the then important Senegal Valley, with the better port of Dakar. The railway achieved this, but unexpectedly did far more for Dakar and Senegal by stimulating the cultivation of peanuts (groundnuts) in the vicinity of its track. The increase in trade led to an extension of the jetty in 1892 and to the building of the port's first breakwater.

Anglo-French rivalries in Africa and British troubles in South Africa caused France in 1898 to decide to establish a naval base at Dakar. As a result, a northern breakwater was built to enclose a large deepwater harbour. The southern jetty was again extended, and a dry dock provided. In 1904 Dakar replaced Gorée as the federal capital of French West Africa. Two more southern piers were built between 1904 and 1910, and other facilities were improved. By 1914 Dakar was a well-equipped port and pleasantly planned town, with a population of almost 24,000.

World War I brought a great increase in the tonnage of shipping using the port; this increase was partly maintained after the war by the opening in 1924 of the Dakar-Bamako-Koulikoro railway line to the French Sudan (now Mali). The railway brought new transit trade to the port, and peanut cultivation was again stimulated in both countries. Between 1926 and 1933 two piers were added near the landward end of the northern breakwater especially for peanut export, supplemented in the later 1930s by the installation of pipelines for the export of peanut oil. These improvements killed the port of Rufisque, about 17 miles to the east, as a peanut-shipping competitor to Dakar. A fuelling pier was also built on Dakar's northern breakwater. Just before World War II the original pier on the southern jetty was further improved, and the breakwater was equipped to discharge oil tankers and refuel other vessels. By 1936 the town's population was almost 93,000.

During World War II Dakar, like all of French West Africa, recognized the authority of the Vichy administration of France in 1940, and the efforts of the Free French, under the leadership of General de Gaulle, to